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Thirsty Energy (II): The Importance of Water for Oil and Gas Extraction

THE BOTTOM LINE

The effect of oil and gas development on local and regional water resources can profoundly change a region's economic possibilities, its water environment, and the vitality of its ecosystem. It is necessary to tackle the water-energy challenge today through technological innovations and institutional changes, such as integrated planning and valuing water as a resource. More information on the Thirsty Energy initiative can be found at www.worldbank.org/thirstyenergy.

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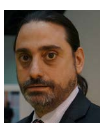

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Why is this issue important?

Water and energy are inextricably linked, but energy development often proceeds without sufficient attention to water's sustainable use

The water requirements needed for oil and gas extraction are often invisible to the public eye. Although oil and gas development is not a significant water consumer when compared to other industries, agriculture, or municipal needs, its water demands can have acute impacts on local water resources and increase conflicts between water users in areas of high water stress or in times of drought. Last year, the United Nations stated that energy development, such as shale gas and oil production, might pose significant risks to water resources and exacerbate tensions between sectors (Patel 2014).

To meet future energy demands, fossil fuels will continue to dominate the fuel mix, with oil, gas, and coal each converging on market shares of around 26–27 percent by 2035, while nuclear, hydropower, and renewables will have a share of around 5–7 percent (BP 2014; Williams 2013). Thirty-eight percent of the world's shale resources are in areas that either are arid or are experiencing extremely high levels of water stress (Reig, Luo, and Proctor 2014). Energy development in eight of the top twenty countries that have recoverable shale gas and tight oil resources, including China, South Africa, Mexico, Egypt, and India, might be curtailed because of that stress. As a result, water concerns will be a major constraint on future oil and gas development (Reig, Luo, and Proctor 2014).

It is possible to assess the effect of fossil fuel development on the water life cycle by the quantity and source of water required for operations; water management practices; recycling, treatment, or disposal of wastewater; and the impacts on the watershed and surrounding environment.

How does water figure in fossil fuel development?

Water is ubiquitous in oil and gas production

Water is used in all stages of oil and gas development, extraction, and processing (WWAP 2014). Operations may consume water or remove large quantities of water; the water is then used for drilling, washing, and processing. The energy sector's water use varies depending on the fuel type, the method of extraction, the geology, the degree of processing required, the geography, and the climate of the site under development. Conversely, constraints on water availability influence the choice of technology in the industry, site selection, and other aspects of resource development.

Figure 1 depicts the range of water required for various energy resources. Biofuels' water needs and environmental impact depend on the crop and whether or not it is rain-fed or irrigated.

When primary production begins in conventional oil production, the natural reservoir pressure is typically sufficient to allow fluids to flow out of the reservoir formation, into the wellbore, and up to the surface. However, as reservoir pressure declines, water is often needed to maintain pressure and to keep up the production rate. In some instances, this primary production phase is followed by secondary recovery processes, such as waterflooding or the injection of treated water, that drive residual oil to the production wells. Offshore conventional oil development makes use of treated seawater for waterflooding, greatly diminishing the use of freshwater (Williams 2013). To extend a field's economic life, a tertiary process to enhance

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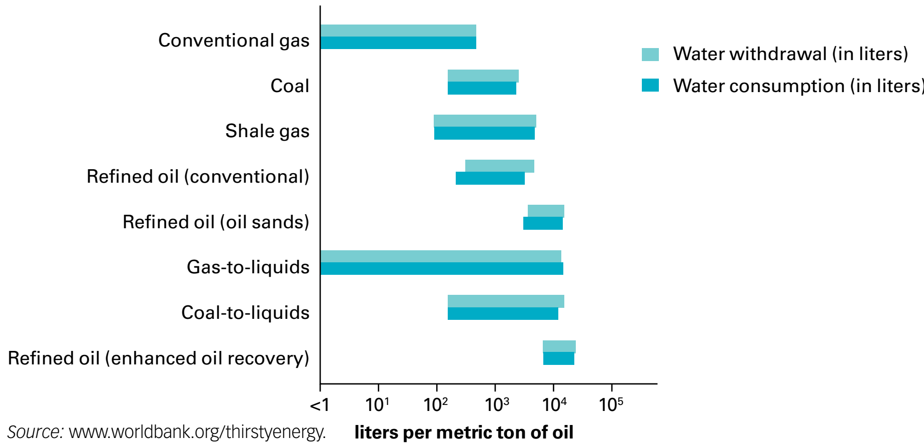
Figure 1. Water demand by fuel type



Source: www.worldbank.org/thirstyenergy.

oil recovery (EOR) is used by injecting gas or steam to pressurize the reservoir and lower the viscosity of the remaining oil.

In conventional gas development, gas is under pressure within the reservoir naturally, thus no water injection is required when a well is developed; instead, the gas spontaneously expands, flows into the wellbore, and then heads up to the surface. In conventional reservoirs, the gas moves through the porous reservoir rock toward the wellbore. As a result, conventional natural gas development primarily consumes water in drilling processes, not in gas stimulation.

Water, therefore, is essential in drilling, pressure maintenance, and all stages of production. Figure 2 shows the interaction of water and energy in the secondary and tertiary processes of conventional oil development.

In comparison, unconventional oil and gas production—such as shale gas or so-called tight oil—harnesses hydrocarbons that are in less-permeable rock formations, of a lesser grade, or more difficult to capture. To develop these resources, alternative means of stimulation and production are required, and processes vary depending on the deposit type—but all involve water.

Oil, gas, and water reach the surface and are separated for export and processing at the refinery; for wastewater disposal; or for recycling and reuse to stimulate future oil recovery.

Broadly, extraction technologies for unconventional oil resources are determined by whether the resource is being accessed by well or by surface mining. In well extraction, techniques are divided into two groups that are based on whether the target energy resource is stimulated by increasing or reducing its viscosity: *Cold production* is used primarily for shale oil, tight oil, or heavy oil. The viscosity of these resources is increased by using horizontal wells that have lateral branches and by then injecting water and chemicals for pressure maintenance. Hydraulic fracturing can also be used to stimulate low-permeability rock formations. *Thermal production* is used to exploit heavy oil and oil sands by reducing viscosity with heat, allowing the target energy resource to flow and be recovered. For surface mining of oil sands and oil shales, purified water is used to extract bitumen from mined sand. Water quality issues raised by surface retorting of oil shales are similar to those raised by mined oil sands.

Figure 3 depicts how shale is fractured hydraulically by using water-based fluids, which are injected at a high pressure into a horizontal well. The gas released from the rock flows back up the well and into the separator, moving with the injected and natural fluid from the geologic formation. The water is then treated and can be exported, disposed of, or recycled for future operations.

The recent development of unconventional fossil fuels has brought international attention to the tension between energy and water. The production of unconventional fuels requires more water than conventional gas fuels, but less than conventional oils (Kuwayama 2015). On average, hydraulic fracturing in the United States requires an estimated 2–5 million gallons of water per well (Allen 2013). Uncertainty regarding water use within an oil field that is under development can be as great as or greater than the variability of water use between fields in different regions. As new projects expand across countries such as the United States, United Kingdom, Poland, and Argentina, industry officials and politicians have a historic opportunity to correlate the water needs of energy extraction with sustainable water management practices.

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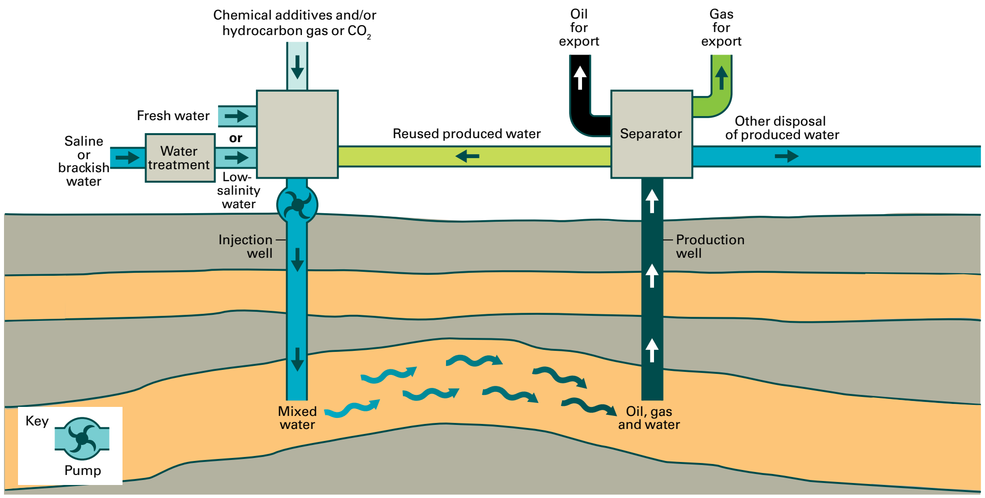
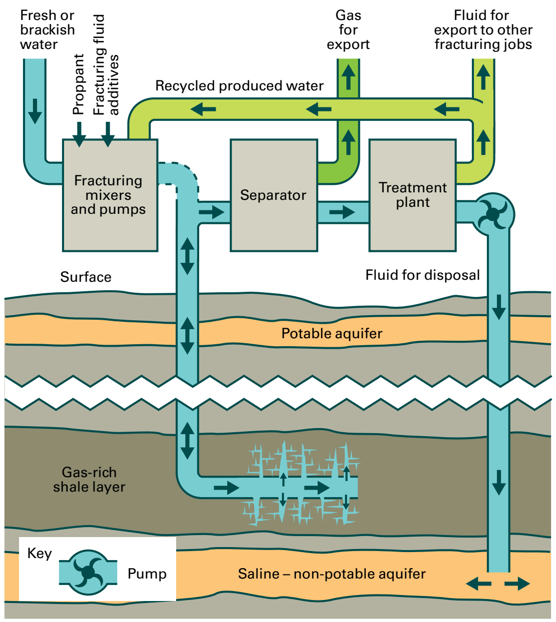
Figure 2. Water use in the secondary and tertiary processes of conventional oil development



Source: Williams and Simmons 2013.

Figure 3. Water use in unconventional natural gas production in shale



Source: Williams and Simmons 2013.

Why is water use by the oil and gas industry a problem?

Concerns are growing about the sector's demand for water and about preserving water quality

Sustainable water management practices are needed to prevent oil and gas operations from increasing water use to the point that it threatens use by other sectors and from damaging the surrounding environment's water quality through spills, leaks, inefficient treatment of wastewater, and other contamination events.

When assessing the effect of oil and gas production on the quantity of water resources, it is important to consider water use in the local context. For example, in the Eagle Ford shale region in Texas, water consumption by the shale gas industry represents about 5 percent of total water consumption in the counties under development (relative to less than 1 percent statewide) but is projected to increase to 89 percent of total use during peak production (Kuwayama 2015). If the state of Coahuila, Mexico, eventually uses the same amount of water for fracking as Texas now does, it is anticipated that oil and gas operations will require nearly one-third of the 1.96 billion cubic meters of the water used annually in Coahuila by all sectors (Schneider 2015). Oil and gas operations can, therefore, greatly affect water availability in time and place, and the operation's consumption of those resources may affect other sectors' water usage. Where water is scarce, oil and gas development has a greater impact on other water use than it does where water is plentiful.

The amount of freshwater required in energy extraction is dictated by the ability to substitute water, the quality of the water, the reservoir characteristics, and the recycling infrastructure. In regions where freshwater is scarce or in high demand for other uses, energy extraction operations may use alternate sources of water, such as saline water or recycled wastewater. During production, the water that returns to the surface carrying oil or gas is known as flowback, or produced water, and it can be recycled. Although recycling water is an important aspect of water management in many regions, wells that return less water to the surface or inadequate recycling facilities can limit the impact of recycling. In the arid Middle East, companies use seawater and brackish water in offshore drilling, consuming no freshwater at all.

Hydraulic fracturing may pose a greater threat to water quality than quantity. In hydraulic fracturing development, surface water bodies may become contaminated by the accidental release of fracturing fluid, flowback, produced water, or partially treated wastewater. Increased concentrations of chloride, bromide, suspended solids, and radionuclides have been documented downstream of treatment plants that handle wastewater from energy extraction; the release of these chemicals harms aquatic wildlife (Kuwayama 2015). Two U.S. federal agencies found that contaminated groundwater was coming from hydraulic fracturing activities in Pavillion, Wyoming (EPA 2011). In Alberta, Canada, energy developers contaminated groundwater by overstimulating a well (ERC Board 2010).

Even in the context of the Middle East's low water use for energy development, conventional oil and fossil fuel extraction can damage water quality through tailings seepage, flowback, or produced water from operations. In Ecuador, an oil spill polluted drinking water, cutting off 80,000 people's water supply (BBC 2013). In Nigeria, oil exploration and the resulting spills profoundly degraded the environment (UNEP 2011).

> "With increased data collection, accessibility, and improved water management, it should be possible for energy resources to be managed within the local water context, the natural precipitation regime, and available water resources."

What is the way forward?

We must find and exploit ways to decrease the impact of oil and gas development on local water resources

As demand for water and energy grows in response to population and economic growth, and as climate change affects the pattern and reliability of energy and water supply and usage, energy companies have sought to develop policies that fully account for their impact on water resources. With increased data collection, accessibility, and improved water management, it should be possible for energy resources to be managed within the local water context, the natural precipitation regime, and available water resources.

Companies and governments are employing a range of approaches for improving water management and regulation in an effort to reduce the effects of oil and gas production on water resources.

Technical improvements in the areas of wastewater reuse and recycling should be maximized in operations because the improvements decrease operational costs and increase the sustainability of operations. In Wyoming, operating companies have been piping produced water from wells to a central gathering system (CGS) that then treats and returns the produced water to companies for reuse in future operations. Such recycling systems allow companies to minimize transportation costs by piping liquids from the well to the treatment facility as opposed to using trucks (Sohns 2014). In the Marcellus shale field, high disposal costs were a key driver for the attainment of nearly 90 percent reuse of produced water. One company conducting hydraulic fracturing operations in the Marcellus field estimated annual cost savings of $3.2 million due to greater water reuse (DOE 2013). Wastewater from conventional oil development in California has also been reused to help severely drought-afflicted agricultural counties irrigate crops (Schlanger 2015).

Petroleum engineers are developing technologies that can help stimulate unconventional resources through a form of hydraulic fracturing that replaces water with liquid nitrogen or uses a super-critical fluid of chilled carbon dioxide. This and other advances will bring previously uneconomical fuel sources to market. The viability of various sources in light of economics and water constraints determines the fuel that is available for power generation, affecting water savings across the entire energy generation life cycle. For example, where there has been a growing supply of natural gas from unconventional gas resources, there also has been increased construction of natural gas combined cycle (NGCC) power plants that consume approximately half as much water as coal-fired power plants.

Governments and energy planners recognize that today's choices and investments will determine what energy mix meets future demands; how innovations will be welcomed into the market; and, therefore, what impact energy extraction will have on water development. Integrated planning of water and energy infrastructures can increase efficiencies and generate new resources. Piping networks and CGS infrastructure highlight how coordinated energy development and water reuse can benefit the environment and the economy. A recent study found that the volume of gas flared in Texas in 2012 would be sufficient to cover the thermal energy requirements needed to treat wastewater for use in hydraulically fracturing in 9,400–28,000 wells (Glazer 2014). Innovative synergies, such as using flared natural gas to power wastewater treatment on site, will save money, diminish freshwater demands, decrease the energy needs of water, and protect the environment.

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Challenges to water and energy planning remain, including creating new impact-assessment strategies that account for local and regional variability when estimating water-related impacts of energy development and production (Mauter 2014). The rapid expansion of drilling and energy development emphasizes that new research aimed at quantifying water-quality impacts, characterizing their pathways, and assessing options will be of high value to the industry and local governments (Kuwayama 2015). Further collection and dissemination of data will improve water and energy resource management, and quality metrics can be created to help regional policy making and advance integrated development (Spang 2014).

International collaboration and public-private partnerships should disseminate best practices to catalyze innovation and improve regulations. The World Bank's Thirsty Energy initiative, for example, assists countries in analyzing water and energy resources to improve long-term sustainability of operations and integrate energy and water planning within government agencies and the sectors.

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